

# How Well Do LED Products Perform in the Real World?

## Review of tracking performance



Solid-State Lighting Market Introduction Workshop  
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- Tracking performance
  - Contracts/warranty
- Issues of analysis and performance
  - Measurements
  - Lamp lumen depreciation
  - Luminaire dirt depreciation
- Economics
  - Manual measurements
  - Mobile/automated measurements
- Verification of metrics
  - Field
  - Laboratory

- Concern
  - Sites concerned about life & cost try to mitigate it with requirements
  - Contract / warranty language defining life or a certain lumen maintenance value
- Example
  - “...rate not to exceed 10% from the start of operation to the conclusion of the 36 month warranty period”
- Task
  - Measuring lamp lumen & dirt depreciation
  - Managing the data
  - Paying for the costs
  - Analyzing the data



*Photo courtesy: Akoya*

- **Measurement Error**
  - 4% output between different samples
  - 2.4% difference between goniophotometer and integrating sphere
  - 2% difference between laboratories
- **Sample Size**
  - More than 1 is needed
  - More samples desirable / trade off with cost
  - Warranty hard to enforce with a sample size of 1
- **Pre-installation Measurements**
  - Cannot rely on manufacturer data (internal QA/QC)
  - Significant measurement errors could be introduced if not pre tested
  - Testing, documenting, installing, and retesting of same sample at same lab is ideal

# Lamp Lumen Depreciation, Initial Output?

Date		Data source	Lumens	Power	lm/W
Lum. 1	Feb. 2008	.IES file	6,462	108 W	59.8
	Sep. 2008	Data sheet	Not listed	108 W	N/A
	Oct. 2010	Data sheet	7,450	104 W	71.6
	“Clean” March 2011	Tested (.IES file)	6,044	108W	56.0
Lum. 2	May 2009	.IES file	9,912	140 W	70.8
	Oct. 2010	Data sheet	9,800 (nominal)	138 W	71.0
	“Clean” March 2011	Tested (.IES file)	5,908	82 W	72.0

- Lum 1
  - Claims device increases power over time for LLF >0.95
  - $6,044/6,462 = 0.935$
- Lum 2
  - Spot measurements found luminaire shipped with wrong driver
  - Normalize input power to estimate LLD?

- Value of TM-21 extrapolation
  - Industry established method of extrapolating lumen maintenance
  - Allows for a possible correlation with projections from measurements at future points in time
- Limitation of TM-21
  - Only applicable to a luminaire that operates at a constant drive current
  - Requires data to be gathered and then calculated

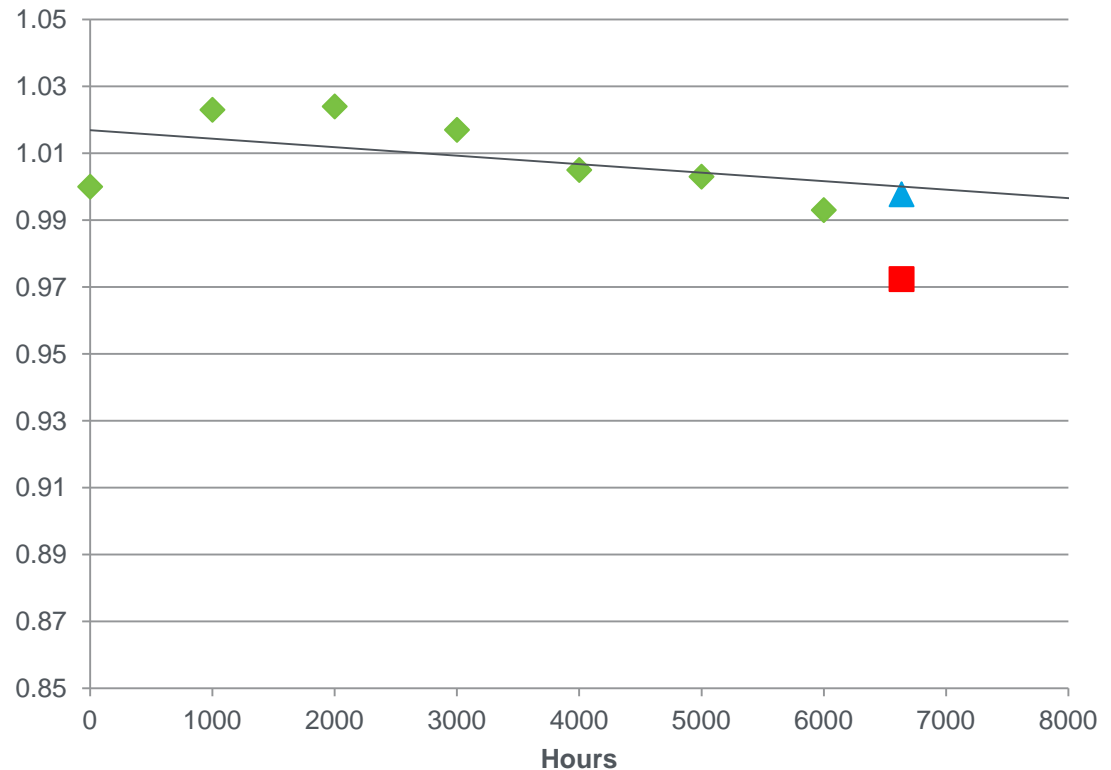
- Drive current
  - Luminaires are offered at multiple drive currents
  - LM-80 data is not always available at the desired drive current
- Temperature measurement point
  - TMP values not often provided on data sheets
  - LM-80 data should bookend (or be higher than) actual operating temperature of the chips
- LED chips
  - Not all luminaire manufacturers provide specific LED information
  - Not all luminaire manufacturers link to LM-80 data of LEDs
- LM-80 data
  - Not always easily available on chip manufacturers' websites

# Lamp Lumen Depreciation, TM-21

## Points:

- Green diamonds are LM-80 (20 LED samples)
- Blue triangle is @ 6,636 hours using formula
- Red square (1 luminaire sample) is calculated LLD based on measurements
- Temperature limitations – red 38° C (case temp) – green/blue at 55° C (junction temp)

Extrapolated LM-80 data



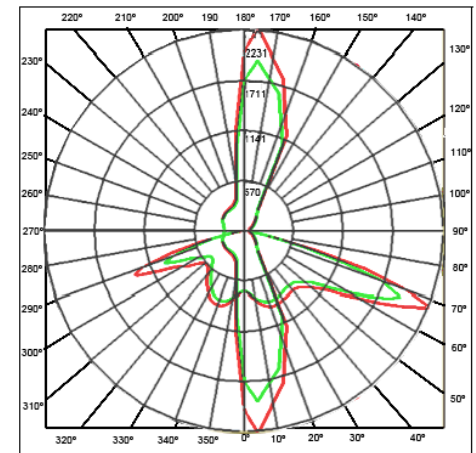
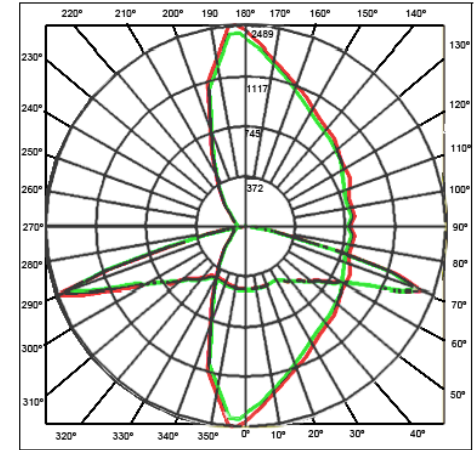


# Luminaire Dirt Depreciation, Is it the rain or air quality?

- Dirt depreciation
  - Longer installation, more depreciation
  - Portland, OR – outlier
- Possible reasons for outlier
  - Rain in NW?
  - Luminaire construction?
  - More samples needed
- LDDs from state DOT documents
  - 0.64 to 0.95
  - Most in the mid 0.80s

Location	Installation (yrs)	LDD
Portland, OR	2.42	0.995
New York, NY	1.58	0.971
New York, NY	1.58	0.960
New York, NY	1.58	0.957
New York, NY	1.58	0.943
Oakland, CA	2.50	0.935
Oakland, CA	3.42	0.889

- Comparison of distributions
  - Anecdotal comments that dirt affects distribution
  - Figures compare “clean” & “dirty” luminaires
  - No major differences in distribution, just reduced values for the “dirty”
  - CCT no change between “clean” & “dirty”
- CALiPER
  - 2.4% difference between integrating sphere and goniophotometer
  - Affects potential LLD comparisons / requiring both sphere and gonio



# Economics

## How much are field measurements?



## Field Measurements on FDR Drive in NYC

Photo courtesy: Ryan Pyle

- Equipment needs
  - Trucks for lane / road closure
  - Cones
  - Flags
- Labor needs
  - Staff for each truck
  - Staff traffic control
  - Personnel to take the measurements



*Photo courtesy: Ryan Pyle*



# Economics

## How much are field measurements?

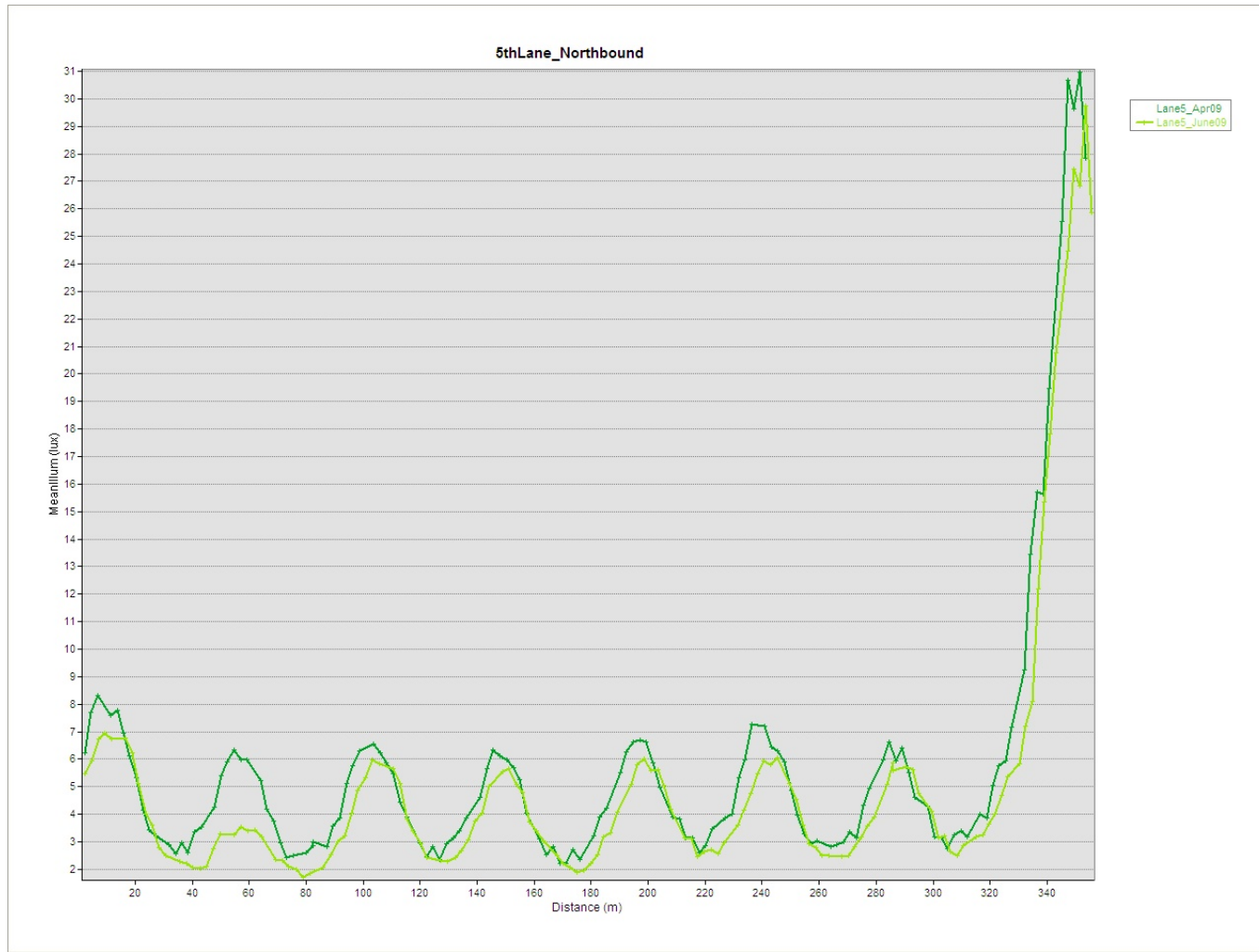


I-35W Bridge – Minneapolis, MN

Photo courtesy: BetaLED

# Economics

## Mobile monitoring device



## I-35W Bridge Field Measurements

- Equipment needs
  - GPS with high accuracy
  - Computer
  - Multiple illuminance meters
  - Mounting hardware to truck
- Labor needs
  - Initial measurements without device
  - Runs with the truck
  - Staff members correlating and analyzing the data

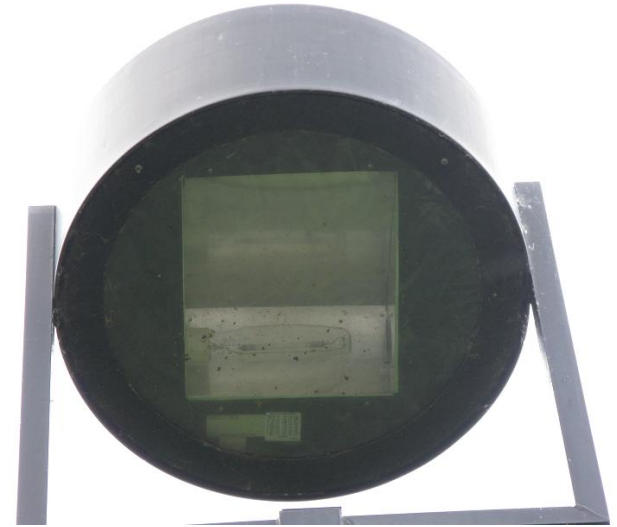


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# Field Measurements

## Advantages, challenges, issues

- Advantages
  - Equipment can remain in place and operating
  - Capture data about the system, not just one luminaire
- Challenges
  - Must be repeated multiple times
  - Costs each time
- Issues
  - Cannot separate LDD from LLD
  - May require multiple field measurement sites in a large metropolis



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# Economics

## Removing luminaires for lab testing

- Equipment needs
  - Replacement head once operating luminaire is removed
  - Truck to remove head(s)
  - Multiple luminaires needed to be removed to provide statistically significant data
- Labor needs
  - Limited crew to remove the luminaire
  - Staff to ship the luminaire to the lab
  - Management of the luminaires, both testing and operating
- Other costs
  - Laboratory testing in both gonio and sphere



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# Laboratory Measurements

## Advantages, challenges, issues

- Advantages
  - Separate LLD, LDD, and other possible issues
  - Provides most information about the luminaire(s)
- Challenges
  - Requires multiple luminaires
  - Removes luminaires from service – limitations to long term management
- Issues
  - Requires multiple sets of luminaires to be tested multiple times
  - Higher costs (labor, materials, testing)
  - Lab-to-lab variations



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# Economics

## How much measurements?

Activity	Type of Measurement Plan	Major Roadway	Minor Roadway	Parking Lot
Support staff (for safety)	Field & Lab	Moving lane closure \$\$\$	Flagger/spotter \$\$	As needed \$
Points marker	Field	GPS \$\$\$	Spray paint or GPS \$	Spray paint \$
Measurement Equipment	Field	Multiple meters \$\$	One meter \$	One meter \$
Data recording	Field	\$\$\$\$	\$	\$
Lab measurements	Lab	Sphere \$\$	Sphere \$\$	Sphere \$\$
Management of luminaires	Field & Lab	Staff time \$	Staff time \$	Staff time \$
Analysis of data	Field & Lab	Staff time \$\$	Staff time \$\$	Staff time \$\$

- If serious:
  - Financially plan for multiple luminaires tested initially in laboratories
  - Do periodic spot measurements in the field
  - After long-term operation, (more than 5 years) test in a laboratory
- Luminaires
  - Require data for TM-21 in bid
  - Require QR (right) be placed on luminaire with information from the initial lab test
  - QR points to database with:
    - Lumens / power input / power factor / color characteristics / critical distribution information / driver information / chip information

